ABSTRACT

Title	Super-High Temperature Alloys and Composites from Nb-W-Cr Systems
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Objective: To develop a new material from Nb-W-Cr system for a possible application with temperature requirements of up to 1500^{o}C.

Accomplishments to Date: The alloys Nb-20W-5Cr and Nb-20W-10Cr have been prepared by the Ames Laboratory of Iowa State University. The as received (AR) samples were in the form of ½ x ½ x 1/16 inch slices. Optical microscopy of the AR samples indicates two phase microstructures in both alloys which does not agree with the ternary section of the Nb-W-Cr phase diagram at 1500^{o}C for the alloy containing 5%Cr. XRD results on AR materials clearly point to the existence of Cr, Nb, and W peaks in the polished form while additional strong peak of carbon has been detected in the unpolished form of the alloys.

Nb-20W-10Cr (10Cr alloy) was oxidized using a ceramic crucible and samples of ¼ x ¼ x 1/16 inch dimension in a computerized temperature controlled furnace in a range of temperature from 700 to 1500^{o}C in air. The crucible was closed with a light ceramic cap on it. Weight gain measurements were made after 24 hours (t) of exposure to air at each temperature after the samples were cooled down to room temperature inside the furnace. The weight gain measurements have been expressed as weight gain per unit area (W) of the surface. A continuous increase in W was observed for the samples tested up to 950^{o}C, then a drop at 1000^{o}C followed by a continuous increase in temperatures up to 1400^{o}C. Surprisingly, partial melting of the alloy has been observed at 1500^{o}C in direct contradiction with the isothermal section of the NB-W-Cr phase diagram shown in Metals Handbook (volume 3, 1999). The alloy disintegrates into complete powder at 800, 850, 900 and 950^{o}C after oxidation while considerable bulk metal was retained at 700 and 750^{o}C. The oxidation at temperatures higher than 950^{o}C results in a mixture of

partial powder and bulky forms with several cracks. However, a clear faceting of the surfaces were observed at 1300 and 1400^oC.

XRD reveals disintegration of the alloy into complete powder form is associated with the formation of CrO which has not been observed at any other temperature. $CrNbO_4$ has been found for alloys subjected to oxidation at temperatures below 1000^oC. The characteristic oxides formed at 1200, 1300, and 1400^oC have been found to be Cr_2O_3 and WO_3. However, Nb_2O_5 appears to be present in all the oxidized samples irrespective of the temperature. Thus this oxide of Nb is the basic oxide developed in this alloy regardless of oxidation temperature. Traces of NbO_2, Cr_2O_5, Cr_5O_{12}, CrO_2, W_3O, and $NbCr_2$ have been detected after oxidation at these temperatures. However, their presence does not follow particular relationship with the oxidation temperatures.

Optical microscopy of the 10Cr alloy subjected to oxidation reveals a definite change in microstructures as a function of temperature. The second phase particles at grain boundaries seen in the AR condition appear to be stable at 700^oC. The microstructures for oxidized samples from 1000 to 1400^oC indicate a black microconstituent (not identified as yet) which coarsens with temperature. A uniform dispersion of second phase particles forms a feature of the sample oxidized at 1400^oC.

Future work: The 10Cr alloy will now be subjected to periods longer than 24 hours in order to determine the long term oxidation characteristics. Scale characterization similar to that was done for 24 hour exposure will be the main theme of analyses. The XPS results will be obtained in order to determine the composition profile in terms of depth of penetration. Microstructural characterization can provide us with the detailed information about the identification and distribution of the microconstituents. The study for the second major alloy, Nb-20W-5Cr has already been started. A 24 hour exposure to air up to 1500^oC is being conducted at this time and then procedure similar to that used for 10Cr alloy will be followed in the research. Alloys with modifiers such as B, C, and Y will be processed by the Ames Laboratory of Iowa State University and will be a subject of study with procedures similar to alloys containing 5 and 10%Cr.

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Kakarlapudi Raju Purushotham (M.S. student)
Abdul Bhuiya (Ph.D. degree)

Conference presentation: "High Temperature Oxidation of Nb-20W-10Cr Alloy in Air up to 1400^oC", Purushotham Kakarlapudi, Shailendra Varma, Ken Natesan, Fifteenth International Symposium on Processing and Fabrication of Advanced Materials (PFAM XV), Materials Science & Technology 2006, Cincinnati, Ohio, October 15-19, 2006, Accepted for presentation.

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